

AXIOMATIC APPROACH TO EVALUATING THE STABILITY OF AUTOMOTIVE GLASS MANUFACTURING

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The stability of the automotive glass manufacturing process with conventional quality control and axiomatic analysis is analyzed. It is shown that conventional quality control can distort the results of analysis. Axiomatic analysis of quality control examines the process on the basis of individual measurements, thereby guaranteeing reliable results.

Key words: automotive glass, stability, axiomatic approach, quality control.

Control charts are widely used in industrial quality control. W. A. Shewhart derived a simple definition of the special reason for variation in a manufacturing process: the points on a control chart run out of range at the top and bottom control limits. He proposed constructing the 3σ limit on control charts and validated this step by many calculations of the probabilities assuming that the parameter of interest is a normally distributed variable.

However, not all samples within the limits are normally distributed. In practice it can happen that all points fall within the limits while the chart shows that something happens with the process: the process has an obvious tendency to increase or decrease, is periodic and so forth.

Ordinarily, at least 15 samples are used in conventional analysis [1]. According to Shewhart's rule the running of out of the range established by the control limits indicates a moment in time when something interferes in the process and control actions must be applied. The use of indicators generalizing many samples smoothes the variability of the process, which can distort the results of an analysis.

Axiomatic analysis of quality control is a statistical method consisting of two steps: checking the uniformity (stability) of a manufacturing process within the limits of each sample and checking the uniformity (stability) of the manufacturing process within the limits of several samples [2]. Axiomatic analysis of the stability of a manufacturing process requires at least four samples. This reduces the cost of analysis considerably and makes checking much more efficient, which is important for control of a manufacturing process.

We shall evaluate the stability of the manufacturing process for automobile windshields, using conventional quality

control and axiomatic analysis. An important indicator for windshields, which are curved, is the deviation of the shape of surface profile from that of a template [3]. The transverse curvature (sag) must not exceed the specifications. The sage fluctuations of glass at the Industrial-Commercial Organization Avtosteklo, AJC Borskii Glass Works, JSC, during 102 shifts are reflected in the graph displayed in Fig. 1. The process falls within the 3σ interval, between the top (TCL) and bottom (BCL) control limits, which are prescribed. According to the conventional analysis using sag as an indicator the glass manufacturing process is stable. At the same time it is evident from the graph that the process tends to rise and fall, i.e., it is characterized by instability.

The erroneous result of the conventional control method can be explained by the fact that the control parameter distribution is not normal (the asymmetry coefficient is 0.24, the excess coefficient is 0.19) and it is incorrect to use the conventional method.

To evaluate process stability by the axiomatic method of analysis we shall assemble 25 samples with four sag measurements in each sample. A check of the stability of the manufacturing process within each sample comprises a check of the representativeness of the sample relative to a homogeneous, invisible, general set [2].

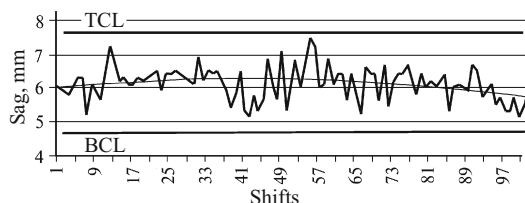


Fig. 1. Variation of windshield sag in the manufacturing process: TCL and BCL) top and bottom control limits, respectively.

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TABLE 1. Results of a Uniformity (Stability) Check of the Manufacturing Process within the Limits for Each Sample

Parameter	Sample												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Uniformity	–	–	–	–	–	+	+	+	–	+	+	–	–

Parameter	Sample												
	14	15	16	17	18	19	20	21	22	23	24	25	
Uniformity	+	+	+	–	–	–	+	+	+	+	+	+	

Notations: +) representative sample; –) nonrepresentative sample.

TABLE 2. Stability of the Manufacturing Process over the Teams

Team	Number of shifts	Samples		
		total	nonrepresentative	representative
1	20	5	2	3
2	12	3	1	2
3	24	6	3	3
4	20	5	3	2

TABLE 3. Results of a Check of the Manufacturing Process Stability in Shifts

Shift	Days	Average value	SD*	Process**
1	1 – 16	6.39	0.50	S
	14 – 29	6.18	0.54	U
2	1 – 16	6.22	0.39	U
	17 – 32	6.29	0.33	S
3	1 – 16	5.95	0.46	U
	17 – 32	6.08	0.59	S

* SD) Standard deviation.

** S and U) stable and unstable respectively.

The results of the uniformity (stability) check of the manufacturing process with the limits of each sample are presented in Table 1.

The process analyzed contains 15 representative and 10 nonrepresentative samples. A representative sample attests that the process is stable and that the final product is of high quality. A nonrepresentative sample shows that the process is unstable; the sag distribution of the automotive glass manufactured is formed under the influence of many factors. They include factors influencing the increase of the full amplitude of the oscillations (unresolved problems, careless operation of the equipment, operator errors and others) as well as factors that cause the sag to deviate from its constant level (poor adjustment of the equipment, change of operators, and others). The axiomatic analysis showed that the windshield manufacturing process is unstable in the samples analyzed (see Fig. 1). The influence of the factors indicated, which disrupt the stability of the manufacturing process, is evident:

the variability on individual sections changes and the process tends to rise and fall.

To work out corrective actions to improve windshield quality it is necessary to evaluate together with other factors ones such as the effect of worker skills in teams and night shifts on product quality.

Automotive glass is manufactured in three shifts by four teams of workers. The quality of the products produced by the teams was analyzed to evaluate the work performed by the teams. The results of the check of the uniformity (stability) of the manufacturing process in the teams are presented in Fig. 2. Each sample consisted of the sag of the manufactured glass in four (successive) work shifts of a team.

The tabulated data make it possible to rank the teams according to the quality of their product: 4, 3, 2, 1. Team number 4 executes the technological process in the most stable manner. Team 2 is less consistent.

To evaluate the effect of the shifts changes on product quality we shall analyze the quality of the product produced by the different teams in the 1st, 2nd and 3rd shifts. Each sample consists of the sag indicators for the glass produced in 16 shifts. There were two such samples for each shift. The results of the check of the stability of the manufacturing process in the shifts are presented in Table 3.

Automotive glass manufacturing in shifts is characterized by instability. The variation of the sag of the glass in shifts is evaluated by the standard deviation, equal to 0.48 mm. The variation of the sag is lowest for the third shift.

The technological process of manufacturing automotive glass analyzed here cannot be regarded as stable. The variability and shift of the average sag vary in magnitude.

A comparative analysis of quality-control methods showed that the conventional method of control can distort the results. An axiomatic analysis of product quality control analyzes the process on the basis of individual measurements, which guarantees reliable conclusions.

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